The Ecology and Acoustic Behavior of Minke Whales in the Hawaiian and Pacific Islands

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LONG-TERM GOALS

The long-term goals of this research project are to improve our understanding of the acoustic ecology and behavior of minke whales in the Hawaiian and Pacific Islands. Our specific goals are to develop and use passive acoustic methods that will allow us to survey, track movements, and monitor acoustic (and eventually non-acoustic behaviors) of minke whales. This will provide important information about the behavioral activities of minke whales at winter areas where they congregate in their breeding season. An additional goal is the assessment of localization accuracy for animals located from seafloor hydrophone arrays. This information is needed to estimate densities of calling animals from fixed hydrophones (e.g. the related DECAF research project). Ultimately, the information and methods resulting from this project will allow for more effective conservation and management of this and other species that are vocally active but visually elusive.

OBJECTIVES

Our objectives are to use passive acoustic methods to detect and locate minke whales in the Hawaiian Islands area from a unique sound they produce called the 'boing'. Once animals are located, we collect detailed information on their acoustic and (when visible) non-acoustic behaviors. We will also conduct acoustic line-transect surveys to estimate the abundance of calling animals in the study area. Animals will be located using passive acoustic methods from a quiet research vessel. These data will be used to validate and assess the localization accuracy of fixed seafloor hydrophone arrays located within the same study area. Acoustic data from the these seafloor hydrophone arrays are being collected concurrently with our vessel-based surveys and will be used in a related effort to estimate densities of calling animals from fixed hydrophones.

APPROACH

The study site is a large (> 2000 km^2) area of deep ocean waters located to west and northwest of the island of Kauai (Figure 1). This area is outfitted with several widespread sea-floor hydrophone arrays that are part of the Pacific Missile Range Facility (PMRF). Approximately 17 hydrophones from these arrays were used to collect acoustic data from calling minke whales by one of our collaborators, (Stephen Martin, SPAWAR). These data were processed in near real-time to localize calls of minke

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2009	**Annual**	**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Ecology And Acoustic Behavior Of Minke Whales In The Hawaiian And Pacific Islands	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Bio-Waves Inc.,517 Cornish Dr.,Encinitas,CA,92024**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Code 1 only

14. ABSTRACT

The long-term goals of this research project are to improve our understanding of the acoustic ecology and behavior of minke whales in the Hawaiian and Pacific Islands. Our specific goals are to develop and use passive acoustic methods that will allow us to survey, track movements, and monitor acoustic (and eventually non-acoustic behaviors) of minke whales. This will provide important information about the behavioral activities of minke whales at winter areas where they congregate in their breeding season. An additional goal is the assessment of localization accuracy for animals located from seafloor hydrophone arrays. This information is needed to estimate densities of calling animals from fixed hydrophones (e.g. the related DECAF research project). Ultimately, the information and methods resulting from this project will allow for more effective conservation and management of this and other species that are vocally active but visually elusive

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

whales. Coincident with this effort, we deployed and monitored a towed hydrophone array system from an acoustically quiet motor-sailing research vessel (R/V Dariabar). Locations of calling animals based on 'boings' localized on the PMRF array were relayed by satellite phone and VHF radio to the R/V Dariabar so that the same animal could be located by our team. Marine mammal observers maintained watches when conditions were suitable and towed hydrophone arrays were used to obtain real-time localizations of calling animals using target-motion analysis. These data were used to independently validate locations of calling animals. Data from both the seafloor hydrophone array and the towed hydrophone array were post-processed to obtain better location estimates and assess sources of uncertainty in the detection and localization processing systems.

WORK COMPLETED

The field season began on 15 March and ended 28 April 2009. The first week of the field effort (leg I) occurred during moderately poor sea conditions (Beaufort 3-4, 2-3m swell) that eventually deteriorated to unworkable conditions (Beaufort 4-7, 3-5m swell) by the end of the second week. A decision was made to halt the field effort until conditions improved. Although acoustic and visual data were collected during this period, visual monitoring was greatly compromised. The second half of the field effort commenced on 19April when weather and sea conditions had greatly improved (Beaufort 1-3, swell < 2m) providing a much better opportunity to collect data.

A total of 21 days consisting of approximately 200 hours was spent at sea (including overnight voyages) for the entire field season (Figure 1). Eleven days of effort of effort were completed for leg I, and 10 days of effort for Leg II Effort was primarily conducted during daylight hours and consisted of both visual and acoustic monitoring. In total, approximately ~ 850 km of survey effort was completed inside the study site. A total of 131.5 hours of multi-channel acoustic data from the towed hydrophone arrays was saved to hard drives.

RESULTS

During surveys from the R/V Dariabar at least 777 boings were manually detected from which numerous localizations were made by the bio-acousticians on watch. Automatic detection of boings is underway and is expected to yield additional detections of boings. We are developing semi-automated methods to analyze the archived towed array acoustic data for localizations. From these analyses, encounter rates and perpendicular distances to animals will be estimated. These data will be used to design the 2010 survey to estimate densities of calling animals.

Case Study: On the morning of the 27 April 2009 (the second to last day of field effort) a solitary animal was localized and tracked at the north end of the study site initially using the PMRF seafloor hydrophone array. This animal was located over 30 km from the R/V Dariabar's position at the southern end of the study area. The research vessel motor-sailed to this area and just before noon began acoustically tracking the animal with the towed hydrophone array. The first towed hydrophone array detection of the animal was estimated to at a distance of approximately 10 km. Within approximately two hours of the animal was sighted by a marine mammal observer very close (100-500m) to the seafloor array localizations. A small boat was launched to collect photo-ID data and record behavioral observations from the minke whale. The animal was photographed and observed for over an hour and was consistently associated with a large flock of seabirds that were following and feeding on schools of small (unidentifiable) baitfish. Although we did not directly observe feeding by

the minke whale, its behavior was consistent with behaviors associated with feeding (e.g. pursuit of fish school, rapid movements, associating with feeding seabirds).

Data from this case study are currently being re-analyzed in detail, focusing most of the effort on the time-period of the sighting. This will allow an assessment of accuracy for the seafloor hydrophone array. Preliminary results indicate that the seafloor array localizations and the visual sighting location are in close agreement [1] (Figure 1). In addition, towed hydrophone array localization methods are being assessed to identify sources of uncertainty and differences in location estimates due to different localizations algorithms used (Figure 2).

IMPACT / APPLCIATIONS

The towed arrays localizations and visual sighting from the R/V Dariabar were significant because they preliminarily confirmed that the accuracy of the seafloor array localization techniques is relatively good. Assessment of localization accuracy is important for validating the assumptions of methods being used in the related DECAF effort to estimate densities of calling animals from fixed hydrophones (Thomas et al. 2008). We will continue to collect data on this aspect of the project as well as work on improving the accuracy and efficiency of localization techniques. This should result in improvements of passive acoustic methods from both fixed and towed hydrophones for estimating animal density and abundance.

New and important information about the acoustic and non-acoustic behaviors of minke whales in their winter/spring (presumably breeding) areas was collected from our first field season. The 2009 season resulted in one of only three documented sightings of minke whales near the main Hawaiian Islands made by a research team in (the second was also by our research team 2006), and the only observations of a minke whales feeding in Hawaiian waters. Feeding behavior for minke whales has never been observed in the Hawaiian Islands, and only very infrequently observed for other commonly seen baleen species such as humpback whales. Acoustic behaviors of minke whales are poorly understood, especially for populations in the North Pacific. We have already determined that there are certain characteristics of the boings that are significantly different for animals from western and central (i.e. Hawaiian) North Pacific, an indication that several populations exist. We will continue to examine the acoustic characteristics of boings for additional insights.

RELATED PROJECTS

A related NOPP funded effort by Len Thomas and collaborators, Density Estimation for Cetaceans from passive Acoustic Fixed sensors (DECAF), is being conducted using some of the data collected from our effort and data from our collaborators. Our data will be used to assess and validate localization accuracy. Localization accuracy is important to assess for the assumptions and methods being developed for the DECAF effort.

Other related projects include efforts to record data from PMRF seafloor arrays to localize and track minke whales using boings. These two projects are being conducted by Stephen Martin (SPAWAR-San Diego, CA) and Eva Nosal (University of Hawaii-SOEST), respectively. Mr. Martin is collecting

[1] There was a time lag of approximately 30 minutes between the last acoustic localization and the sighting because the animal stopped vocalizing when the research vessel turned towards it. However no other animals were vocalizing in the area and no other animals were sighted.

acoustic data from the PMRF hydrophone array concurrently with our field effort. These data were processed in near real-time and are being post-processed by Mr. Martin. Dr. Nosal post-processed the same data from the PMRF seafloor array to estimate localizations using a propagation model-based time-of-arrival (TOA) approach. Results from these efforts will be compared and validated with sighting data and towed array localizations collected from the R/V Dariabar using methods described in this report.

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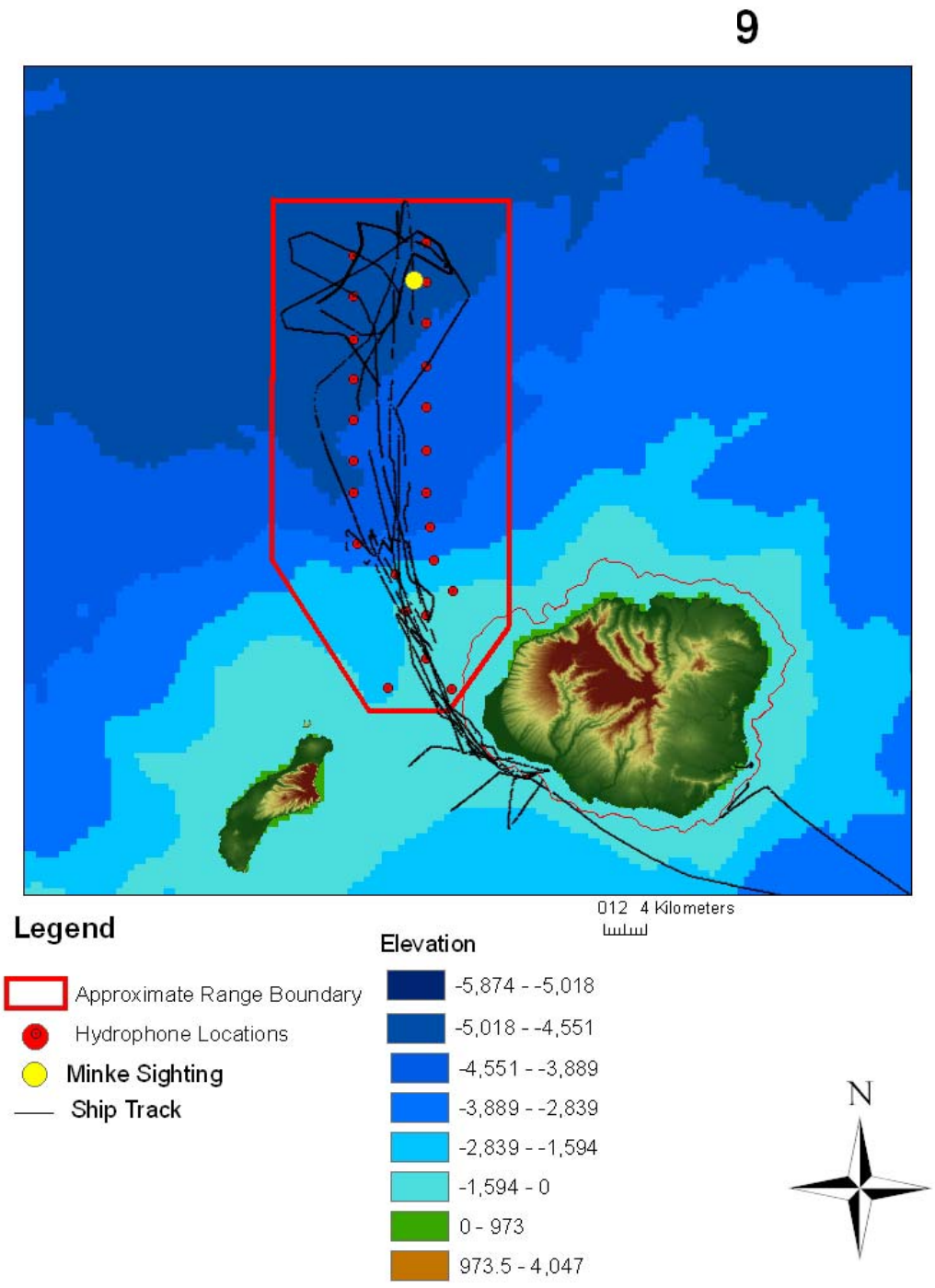

Figure 1. Kauai study area (red polygon, > 2000 km^2) with completed ship tracks by the R/V Dariabar for the 21 days of effort resulting in 800 km surveyed for the 1.5 month field effort. Approximate locations of PMRF seafloor hydrophones used in this study designated by red circles. The visual sighting of a minke whale which occurred after locating it acoustically is designated by yellow circle.

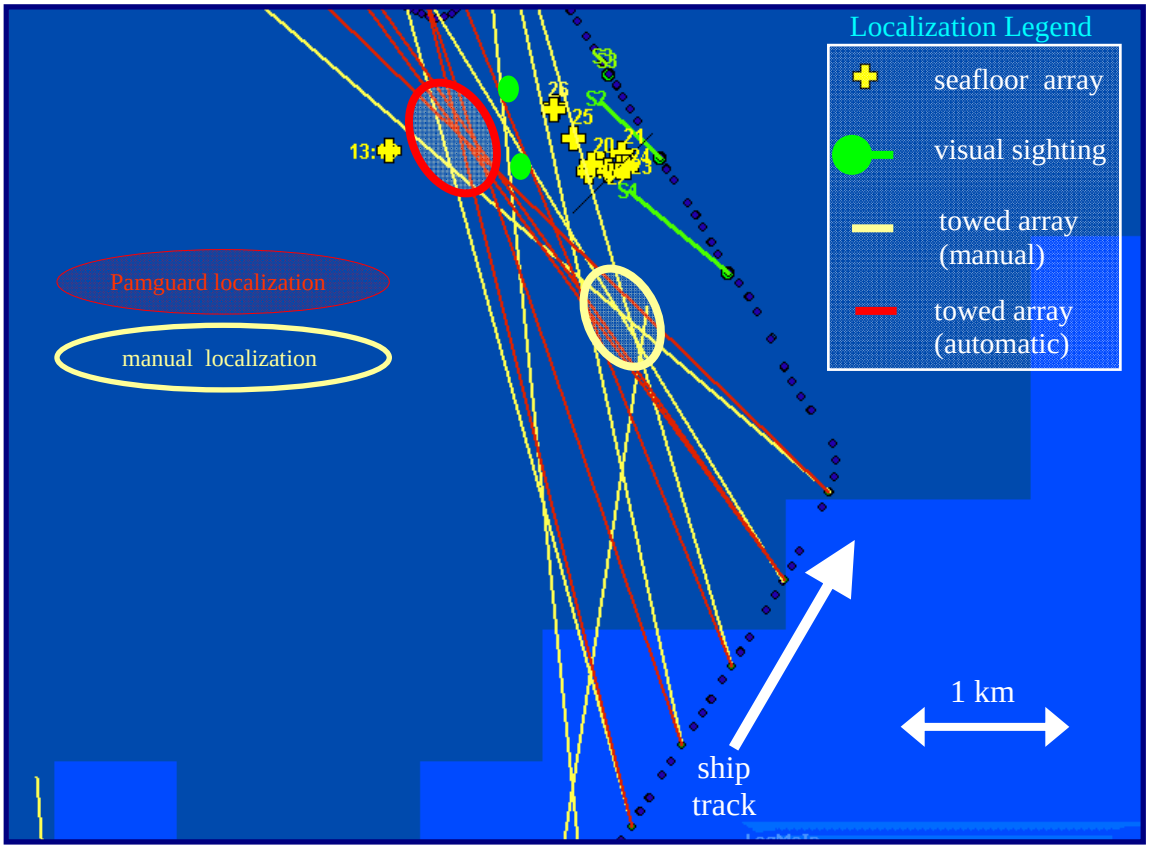

Figure 2. Map of the 27 April visual sightings (green lines) of a minke whale made after the research vessel was vectored towards the region of acoustic localizations made from the seafloor array (yellow crosses). This demonstrates the good agreement of seafloor array localization with the sighted position of the animal. Bearings lines from the towed hydrophone array were processed in real time (sand colored) and semi-automatically post-processed using Pamguard (red). The discrepancy in towed array localization methods is most likely due to uncertainty in the estimated position and heading of the towed hydrophone array.